# The effect of different soil tillage systems on soil physical characteristics and crop yield of main crops from the Moldavian Plain, Romania

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## 1. Abstract

Optimal crop rooting soil physical conditions are a result of complex interactions between soil strength and oxygen and water supply to plant roots. Spatial/temporal variability in soil properties can be critical in the evaluation of the effects of tillage management practice on soil and crop parameters. In this paper tillage were evaluated for theirs effects on soil physical properties. Tillage treatments were plough to 20 cm, plough to 30 cm, chisel and disc harrow applied to wheat in to been/ wheat/ maize rotation. The experiments have been conducted in the Didactic Station of the University of Agricultural Sciences and Veterinary Medicine – Iasi, Ezăreni Farm, during the period between 2002-2006, on a cambic chernozem with 3,7 % humus and pH 6.8. Tillage system modify, at least temporarily, some of the physical properties of soil, such as soil bulk density, penetration resistance, soil porosity and soil structural stability. All the tillage operation was significantly different in heir effects on soil properties. The results indicate that soil tillage systems must be adjusted to plant requirements for crop rotation and to the pedoclimatic conditions of the area.

## 2. Introduction

Soil tillage, besides new and direct effects, good for plant growing technologies, induces in soil long-term residual effects, which act on its physical and physico-mechanical characteristics, by modifying them (Jitareanu et al., 1999). Soil physical characteristics have a major influence on the way of soil functioning within an ecosystem (Carter, 1996). Plant growth and development, water regime and soil solution are tightly connected to soil physical characteristics (Pagliai et al., 2005). According to size, form and forming mode, the soil aggregates may have more or less characteristics favorable to the circulation of water and air, and root penetration (Iris Vogeler et al., 2006). Therefore, the implementation of a certain tillage system must be done in concordance with all the aspects that may be influenced or may influence this system (Horn et al., 1994, Liebig et al., 2004). This requires the detailed knowledge of all elements contributing to soil fertility increase or diminution (Canarache, 1990, Fabrizzi et al., 2005).

## 3. Methods

The experiment was conducted at the Didactic Station of the „Ion Ionescu de la Brad" University of Agricultural Sciences and Veterinary Medicine of Iasi, Ezareni Farm, during farming years 2002-2006. The experimental site is located in the East part of Romania (47$^o$07` N latitude, 27$^o$30` E longitude) on a chambic chernozem (SRTS-2003, or haplic chernozems after WRB-SR, 1998), with a clay-loamy texture, 6.8 pH units, 3.7 % humus content and a medium level of fertilization. The soil has high clay content (38-43%) and is difficult to till when soil moisture is close to the wilting point (12.2%). The experimental site has an annual average temperature of 9,4$^0$C and precipitation of 587 mm. The experimental design was in a "divided plots design" with three replications. We have investigated two variants of the classical soil tillage system – plough at depths of 20 cm and 30 cm– and two variants of minimum tillage – Chisel variant and disk harrow variant – in the crop rotation made of beans/wheat/maize. This paper presents the results obtained in winter wheat and maize growing as concerns the influence of the tillage method on some soil physical characteristics. Soil samples were taken from the fields just after the sowing of each crop, during the vegetation season and right after the harvesting, in order to determine soil bulk density (BD) and total porosity (TP) and efficient porosity (EP). We have also calculated degree of compaction (CD) (Canarache, 1990). For the determination of penetration resistance (PR) we have used the dynamic penetrometer. The analysis of distribution and structure hydrostability (SH) of structural macroaggregates was carried out according to Tiulin-Ericson method and certain indicators as mean weigh diameter (MWD), were determined by calculation (Canarache, 1990). Determinations were carried out at three depths (0-10, 10-20 and 20-30 cm). Statistical processing of data was done by means of the analysis of variance.

**4. Results**

The influence of soil tillage on bulk density (BD) and on layers had a special importance; we could therefore, estimate more accurately how loosening or settling degree has influenced plant development and yield level. Studying the evolution of means values of bulk density after four years of experiencing in winter wheat and maize, we found out that at sowing (layer 0-10 cm), they were between 1.10 and 1.17 g/cm$^3$. The bulk density has increased in layer 10-20 cm, reaching values comprised between 1.23 and 1.28 g/cm$^3$ in ploughed and disk harrow-tilled variants. In the next depth degree (20-30 cm), the differences between variants were very high, minimum values being registered in the case of variant ploughed at 30 cm (1.24 g/cm$^3$) and maxima ones in the case of disk harrow-tilled variant (1.41 g/cm$^3$). The 20 cm ploughed variant had higher values on this depth scale, in comparison with the chisel variant (1.38 g/cm$^3$ respectively, 1.31 g/cm$^3$ in winter wheat crop) (Figure 1 and 2).

During the vegetation period, the bulk density has increased in all variants and at all depths (Figure 1 and 2). In all variants, the most settled layers were upper layers, and this phenomenon diminished at depth; the lowest differences of values of the indicator between the two consecutive moments of sampling were signaled at the disk harrow-tilled variant. In maize crop, after cultivation tillage has been created a compacted layer with values between 1.36 and 1.44 g/cm$^3$, as result as machinery passing for cultivation tillage. At harvesting, the bulk density on analyzed profile had the lowest mean values at the variant plough at 30 cm (1.39 g/cm$^3$), followed by the variant plough at 20 cm (1.42 g/cm$^3$), and chisel and disk harrow variants (1.44 g/cm$^3$) (Figure 1 and 2).

Statistical processing of obtained data, as an average of analyzed profile (0-30 cm) and during the vegetation period, in the four years of experiment, has shown that bulk density had the highest values, with significant differences, compared to the control variant (+3.6 %), at the disk harrow variant in both crops. The variant plough at 20 cm depth and chisel variant had close values between them and also close to the control variant; the variant plough at 30 cm has statistically demonstrated that it decreasing settling degree (Table 1).

Studying the average results of penetration resistance (PR) registered in winter wheat and maize crops, we found out that at sowing, the lowest values were at 0-10 cm layer. At the depth interval of 10-20 cm, because of settling produced by equipments used for seedbed preparation, the values of penetration resistance were high, close to the values shown at the depth of 20-30 cm (Figure 1 and 2).

The both ploughed variants have generally shown lower mean values on profile (17.08 daN/cm$^2$ at plough at 20 cm and 15.38 daN/cm$^2$ at plough at 30 cm in winter wheat crop) than the variants tilled without furrow inverting (18.11 daN/cm$^2$ in Chisel variant and 19.90 daN/cm$^2$ in disk harrow variant). By comparing the values of 20 cm ploughed and Chisel variants on the layer 10-20 cm, we found out that the chisel variant was more loosened, the values of penetration resistance being of 20.97 daN/cm$^2$ compared to 21.90 daN/cm$^2$ at 20 cm ploughed variant in winter wheat crop. In maize crop it was found similar values like in winter wheat crop.

Because of natural processes from the interval sowing-straw elongation, soil was settled and the values of penetration resistance have increased in all the layers until harvesting; this increase was higher at depth of 20-30 cm in the winter wheat crop. In maize crop it was found a compacted layer on 10 cm depth, as results of machinery passing for cultivation tillage (Figure 1 and 2).

During the vegetation period, the penetration resistance has increased in all the variants at the depth of 0-30 cm, this increase being higher at the interval sowing-straw elongation in winter wheat crop and at the depth of 0-20 cm. The lowest values of this index were registered at 30 cm ploughed variant, at all stages and depths, and the highest one, at disk harrow variant. In chisel and 20 cm ploughed variants, the values were intermediary compared to 30 cm ploughed and disk harrow-tilled variants for both crops (Figure 1 and 2).

The statistical analysis of mean values has shown that soil tilled only with disk harrow determined a higher soil settling, with 14% statistically insured difference to the control variant in winter wheat and 16 % in maize crop (Table 1). The treatment plough at 30 cm maintained soil more loosened on studied profile, the difference to the control variant being statistically significant. The chisel tillage led to a higher soil compactation, compared to 20 cm ploughing, but the differences to the control were not statistically insured.

As the absolute values of bulk density or total porosity could not be adequately interpreted, in order to assess the soil settling condition, because their practical significance was different from a type of soil to another, according to it's texture (Canarache, 1990), a complex indicator was calculated, which included bulk density, total porosity, and texture, respectively, degree of compaction (CD) (Stângă, 1978).

Studying data obtained in winter wheat crop, we have noticed that the compaction degree had lower values at sowing and in ploughed layer, for each variant increasing according to depth and in same time with vegetation development. Till harvesting, the values of compaction degree are increasing in both crops. The ploughed variants with furrow inverting are becoming intensely compacted at depth of 10-20 cm, where differences were the biggest. Soil layers, which were not mobilized through soil tillage, were compacted with the lowest intensity, as results as a initial high values of this index.

The values higher than 10 % v/v, which were found at harvesting in the variant plough at 20 cm, chisel and disk harrow variants, at the depth of 20-30 cm, have shown that soil was moderately compactated (according I.C.P.A., 1987). The values between 1 and 10 indicate a weakly compacted soil, which needs loosening of third emergency (Stângă, 1978). Our results have shown that in a short-term interval, the compactation degree did not change significantly, no matter what tillage system has bean used (Table 1). A progressive increase of this parameter was registered from sowing to harvesting and according to depth, in all soil tillage variants.

The values of total porosity (TP) decrease from sowing to harvesting in all tillage systems variants for both crops. The statistical interpretation of mean values has shown that 30 cm ploughed variant determined an increase of total porosity at 0-30 cm layer, with a statistically insured difference of almost three percentages, compared to the control variant (Table 1). Aeration porosity becomes smaller at the same time with depth increasing, in all vegetation stages, in all soil tillage systems. Efficient porosity (EP) was not significantly influenced by depth, growing stages or tillage systems (Table 1).

**Table 1 Influence of tillage systems on some indicators of soil compaction condition**

| Crop / Tillage systems | Winter wheat | | | | | Maize | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | BD ($g/cm^3$) | PR ($daN/cm^2$) | CD (% v/v) | TP (% v/v) | EP (% v/v) | BD ($g/cm^3$) | PR ($daN/cm^2$) | CD (% v/v) | TP (% v/v) | EP (% v/v) |
| Disk harrow | $1.38^{x}$ | $25.3^{xx}$ | 5.29 | $47.7^{o}$ | 13,8 | $1.38^{xxx}$ | $25.1^{xxx}$ | 5.15 | $47.8^{ooo}$ | 13,7 |
| Chisel | 1.35 | 22.7 | 2.43 | 49.2 | 13,9 | 1.34 | 22.2 | 1.88 | 49.5 | 13,9 |
| Plough to 20 cm | 1.34 | 21.2 | 1.72 | 49.6 | 13,9 | 1.33 | 20.9 | 0.89 | 50.0 | 13,8 |
| Plough to 30 cm | $1.29^{o}$ | $19.0^{oo}$ | -1.69 | $51.3^{x}$ | 14.0 | $1.29^{oo}$ | $18.2^{ooo}$ | -1.85 | $51.4^{xx}$ | 14,0 |
| Control variant (C.V.)– mean value for all variants | | | | | | | | | | |
| $LSD_{5\%}$= | 0.04 | 1.5 | | 1.5 | 1,0 | 0.02 | 1.1 | | 0.8 | 0,1 |
| $LSD_{1\%}$= | 0.06 | 2.2 | | 2.2 | 1,5 | 0.03 | 1.7 | | 1.2 | 0,2 |
| $LSD_{0.1\%}$ = | 0.09 | 3.6 | | 3.6 | 2,4 | 0.05 | 2.7 | | 1.9 | 0,3 |

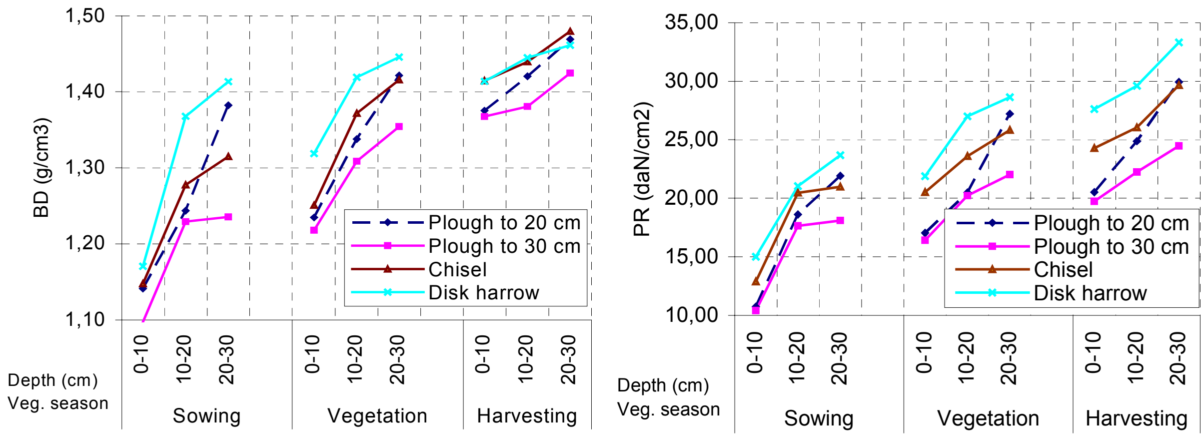



**Figure 1 The dynamic of BD and PR on winter wheat crop**

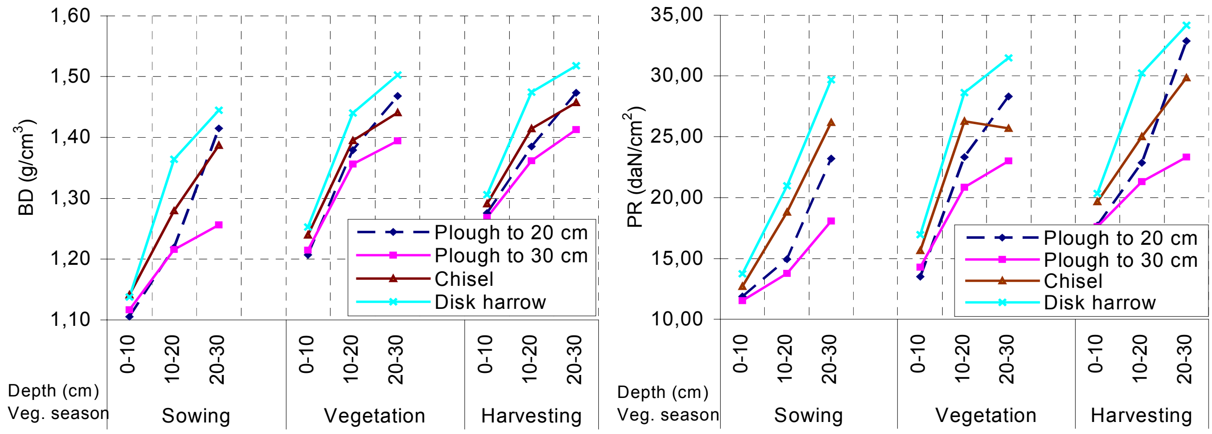



**Figure 2 The dynamic of BD and PR on maize crop**

The mean weigh diameter (WMD) of structural aggregates has recorded a decreasing in vegetation period on layers 0-10 and 10-20 cm, and a slight increase till harvesting. At the depth of 20-30 cm, where the effect of conservation practices was not felt, the diameter of aggregates has increased constantly till harvesting.

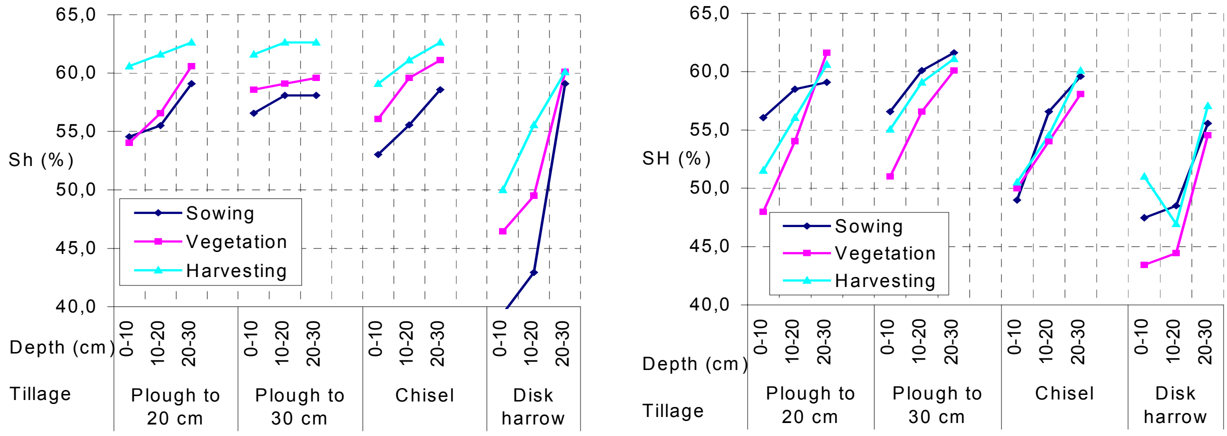
The statistical analysis of mean values has shown that the chisel treatment has favored the intensification of structure formation, finding on this variant aggregates with agronomic value, as effect of accumulation of organic matter at soil surface (Table 2). Disk harrow tillage and the cultivation treatment lead to mechanical destruction of soil aggregates, this assessment being supported by statistically insured differences.

The structure hydrostability (SH), indifferently of the vegetation stage or tillage variant, has increased with depth, having a peak value in the 20-30 cm layer. The tilled variants without furrow inverting had high values of structure hydrostability in upper layers (0-10 and 10-20 cm). In the Chisel variant it has bean recorded the best structure hydrostability, at depth of 20-30 cm (Figure 3, a, b).

The statistical analysis of mean values on profile and for the entire vegetation period has classified the variants according to data presented in table 2, the differences between variants being greater, and the differences compared to the control variant is statistically significant. The greatest structure hydrostability on the analyzed profile was determined at the plough at 30 cm variant, due to higher values of the indicator on 20-30 cm layer, in comparison with the same depth for all other treatments. In comparison with the control variant, the statistically insured negative differences were found only at the disk harrow variant. These tendencies are relevant for the both crops.

**Table 2 Influence of tillage systems on some indicators of soil structure**

| Crop / Tillage systems | Winter wheat | | Maize | |
|---|---|---|---|---|
| | SH (% v/v) | MWD (% v/v) | SH (% v/v) | MWD (% v/v) |
| Plough to 30 cm | 59.6 | 6.16 | 57.9xx | 5.69 |
| Plough to 20 cm | 58.4 | 6.52 | 56.2 | 5.75 |
| Chisel | 58.5 | 6.81 | 54.7 | 6.30xxx |
| Disk harrow | 51.5 | 5.54 | 49.9ooo | 4.28ooo |
| Control variant (C.V.)– mean value for all variants | | | | |
| $LSD_{5\%}$= | 2.5 | 0.6 | 1.8 | 0.3 |
| $LSD_{1\%}$= | 3.7 | 0.9 | 2.7 | 0.5 |
| $LSD_{0.1\%}$ = | 6.0 | 1.4 | 4.4 | 0.8 |




(a) (b)

**Figure 3 The dynamic of SH on winter whet (a) and maize crop (b)**

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